UNIT 8

10–15% AP EXAM WEIGHTING

~12–17 CLASS PERIODS

Fluids

Developing Understanding

In Unit 8, students consider how the forces and conservation laws studied in Units 1 through 4 can be applied to the study of ideal fluids. Unit 8 ties together the thematic threads that have been woven throughout the course, including the interactions between systems and the conservation of fundamental quantities.

ESSENTIAL QUESTIONS

- Why do some objects float while others sink?
- Why is an object's ability to float an important characteristic?
- What implications to our lives would there be if nothing floated?
- Why don't we feel the miles of air above us pushing us down?

Building the Science Practices

1.A 1.B 1.C 2.A 2.B 2.C 2.D 3.A 3.B 3.C

Unit 8, the culminating unit of the course, incorporates all the physics principles and course skills students have encountered in previous units, with an emphasis on representations and models (**1.A** and **1.C**) and connecting related knowledge between fundamental ideas. In this unit, students will use familiar force and energy representations (e.g., free-body diagrams and energy bar charts) to describe static and dynamic fluids. Students will also once again be encouraged to sharpen their understanding of mathematics and the laws of physics by being asked to reason with equations to describe a phenomenon (**2.A**, **2.B**, **2.C**, and **2.D**). Additionally, as in the other seven units of the course, being able to identify and describe the relationships between physical quantities—and use these relationships as evidence to make and justify claims (**3.B** and **3.C**)—is a critical skill when answering scientific questions. Inquiry experiences with fluid statics and dynamics can play an integral role in helping students overcome misconceptions. Providing them with opportunities to develop their own scientific experiments (**3.A**), and collect and plot data (**1.B**), will further prepare students for the AP Physics 1 Exam by deepening their understanding of the behaviors of fluids.

Preparing for the AP Exam

Throughout their study of physics, students may need to reflect upon common misconceptions. For example, students may believe that objects float in water because the objects are "lighter" than water, or that objects sink in water because they are "heavier" than water. Misconceptions can be challenged by encouraging students to identify the fundamental physical principle needed to answer a question, which will help them eliminate irrelevant or extraneous information. On the AP Physics 1 Exam, it is also important that students use correct vocabulary and terminology when defending claims with evidence. Students can inadvertently miscommunicate their answer by using words incorrectly or not fully understanding their nuances. For example, students should know the difference between the meanings of "mass," "volume," "weight," "size," and "density." Providing scaffolded instruction in correct vocabulary use and clear, concise explanations will help students be more successful on the free-response section of the AP Exam, where written expression and justification represent many of the available points.

UNIT AT A GLANCE

Topic	Suggested Skills
8.1 Internal Structure and Density	1.B Create quantitative graphs with appropriate scales and units, including plotting data. 2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway. 2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. 3.A Create experimental procedures that are appropriate for a given scientific question. 3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
8.2 Pressure	1.C Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system. 2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway. 2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. 3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
8.3 Fluids and Newton's Laws	1.A Create diagrams, tables, charts, or schematics to represent physical situations. 2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway. 2.D Predict new values or factors of change of physical quantities using functional dependence between variables. 3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
8.4 Fluids and Conservation Laws	1.B Create quantitative graphs with appropriate scales and units, including plotting data. 2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway. 2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. 3.A Create experimental procedures that are appropriate for a given scientific question. 3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Go to **AP Classroom** to assign the **Progress Check** for Unit 8.
Review the results in class to identify and address any student misunderstandings.

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are optional and are offered to provide possible ways to incorporate various instructional approaches in the classroom. Teachers do not need to use these activities or instructional approaches and are free to alter or edit them. The examples below were developed in partnership with teachers from the AP community to share ways that they approach teaching some of the topics in this unit. Please refer to the Instructional Approaches section beginning on p. 153 for more examples of activities and strategies.

Activity	Topic	Sample Activity
1	8.2	**Construct an Argument** Search "pressure versus height graph" online and download a graph of air pressure as a function of elevation. Have students explain why the slope decreases with elevation (air gets less dense) and use the slope of the graph at one point to estimate the density of air at that elevation.
2	8.3	**Desktop Experiment Task** Divide students into groups. Give each group an irregularly shaped metal object (e.g., a small, inexpensive statue). Provide each group a spring scale and access to a deep sink. Have students use buoyancy principles to calculate the volume and density of the object.
3	8.3	**Graph and Switch** Have a student use a rope to raise an object 2 m from the bottom of a 3 m deep pool. Graph (with numerical scales) tension versus height of the bottom of the object above the floor of the pool for 0–4 m. Have another student determine the mass, volume, and density of the object. The shape of the graph from 1 to 3 m also determines whether the shape is a cube, sphere, or a cone pointing up or down. Ask students to switch graphs and discuss.
4	8.4	**Construct an Argument** Have students draw Bernoulli bar charts for two or more points in a flowing fluid situation. (Bars are for pressure, $\rho g y$, and $\frac{1}{2}\rho v^2$.) Examples: water leaking out of a hole in a container, water shooting out of a hose, and drinking from a straw. Have students make and defend a claim about the pressure in two different places in the container, hose, or straw, using the bar chart as evidence.
5	8.4	**Desktop Experiment Task** Divide students into groups. Obtain a syringe (no needle) or water squirter for each group. Have each group fill it with water and squirt the water horizontally. Then, have each group determine how much pressure (for the water squirter) or force (for the syringe) was exerted to make the water come out.

SUGGESTED SKILLS

1.B
Create quantitative graphs with appropriate scales and units, including plotting data.

2.B
Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

2.C
Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.A
Create experimental procedures that are appropriate for a given scientific question.

3.C
Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws

TOPIC 8.1
Internal Structure and Density

Required Course Content

LEARNING OBJECTIVE

8.1.A
Describe the properties of a fluid.

ESSENTIAL KNOWLEDGE

8.1.A.1
Distinguishing properties of solids, liquids, and gases stem from the varying interactions between atoms and molecules.

8.1.A.2
A fluid is a substance that has no fixed shape.

8.1.A.3
Fluids can be characterized by their density. Density is defined as a ratio of mass to volume.

Relevant equation:

$$\rho = \frac{m}{V}$$

8.1.A.4
An ideal fluid is incompressible and has no viscosity.

TOPIC 8.2
Pressure

Required Course Content

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
8.2.A Describe the pressure exerted on a surface by a given force.	**8.2.A.1** Pressure is defined as the magnitude of the perpendicular force component exerted per unit area over a given surface area, as described by the equation $P = \frac{F_{\perp}}{A}$. **8.2.A.2** Pressure is a scalar quantity. **8.2.A.3** The volume and density of a given amount of an incompressible fluid is constant regardless of the pressure exerted on that fluid.
8.2.B Describe the pressure exerted by a fluid.	**8.2.B.1** The pressure exerted by a fluid is the result of the entirety of the interactions between the fluid's constituent particles and the surface with which those particles interact. **8.2.B.2** The absolute pressure of a fluid at a given point is equal to the sum of a reference pressure P_0, such as the atmospheric pressure P_{atm}, and the gauge pressure P_{gauge}. *Relevant equation:* $P = P_0 + \rho g h$ **8.2.B.3** The gauge pressure of a vertical column of fluid is described by the equation $P_{gauge} = \rho g h$.

SUGGESTED SKILLS

1.C Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system.

2.B Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

SUGGESTED SKILLS

1.A
Create diagrams, tables, charts, or schematics to represent physical situations.

2.A
Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.D
Predict new values or factors of change of physical quantities using functional dependence between variables.

3.B
Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

TOPIC 8.3
Fluids and Newton's Laws

Required Course Content

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
8.3.A Describe the conditions under which a fluid's velocity changes.	**8.3.A.1** Newton's laws can be used to describe the motion of particles within a fluid. **8.3.A.2** The macroscopic behavior of a fluid is a result of the internal interactions between the fluid's constituent particles and external forces exerted on the fluid.
8.3.B Describe the buoyant force exerted on an object interacting with a fluid.	**8.3.B.1** The buoyant force is a net upward force exerted on an object by a fluid. **8.3.B.2** The buoyant force exerted on an object by a fluid is a result of the collective forces exerted on the object by the particles making up the fluid. **8.3.B.3** The magnitude of the buoyant force exerted on an object by a fluid is equivalent to the weight of the fluid displaced by the object. *Relevant equation:* $F_b = \rho V g$

TOPIC 8.4

Fluids and Conservation Laws

Required Course Content

LEARNING OBJECTIVE

8.4.A

Describe the flow of an incompressible fluid through a cross-sectional area by using mass conservation.

ESSENTIAL KNOWLEDGE

8.4.A.1

A difference in pressure between two locations causes a fluid to flow.

8.4.A.1.i

The rate at which matter enters a fluid-filled tube open at both ends must equal the rate at which matter exits the tube.

8.4.A.1.ii

The rate at which matter flows into a location is proportional to the cross-sectional area of the flow and the speed at which the fluid flows.

Derived equation:

$$\frac{V}{t} = Av$$

8.4.A.2

The continuity equation for fluid flow describes conservation of mass flow rate in incompressible fluids.

Relevant equation:

$$A_1 v_1 = A_2 v_2$$

SUGGESTED SKILLS

1.B
Create quantitative graphs with appropriate scales and units, including plotting data.

2.A
Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.C
Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.A
Create experimental procedures that are appropriate for a given scientific question.

3.B
Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

LEARNING OBJECTIVE

8.4.B

Describe the flow of a fluid as a result of a difference in energy between two locations within the fluid–Earth system.

ESSENTIAL KNOWLEDGE

8.4.B.1

A difference in gravitational potential energies between two locations in a fluid will result in a difference in kinetic energy and pressure between those two locations that is described by conservation laws.

8.4.B.2

Bernoulli's equation describes the conservation of mechanical energy in fluid flow.

Relevant equation:

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

8.4.B.3

Torricelli's theorem relates the speed of a fluid exiting an opening to the difference in height between the opening and the top surface of the fluid and can be derived from conservation of energy principles.

Derived equation:

$$v = \sqrt{2g\Delta y}$$

BOUNDARY STATEMENT

All fluids will be assumed to be ideal, and all pipes are assumed to be completely filled by the fluid, unless otherwise stated.